

Molluscan fauna of the “Miocene” Maéjima Formation in Maéjima Island, Okayama Prefecture, southwest Japan

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Received August 2, 2001; Revised manuscript accepted January 15, 2002



Abstract. Molluscan fauna of the “Miocene” Maéjima Formation is examined from taxonomical, biostratigraphical and paleozoogeographical points of view. It is composed of four gastropods and 14 bivalves including a new species. Two assemblages, the *Isognomon* and the *Megangulus-Acila* assemblage, were discriminated. The *Isognomon* assemblage is autochthonous or para-autochthonous and is composed of elements inhabited the littoral to upper sublittoral gravelly to rocky bottom in a warm sea. The *Megangulus-Acila* assemblage represents a mixed composition between muddy sand and gravelly to rocky bottom elements, and was formed in an upper sublittoral muddy bottom near a rocky shore. Occurrences of *Megangulus maximus* (Nagao), *Isognomon (Hippochaeta) hataii* Noda and Furuichi and *Chlamys (Leochlamys) namigataensis* (Ozaki) indicate the age of the Maéjima Formation as the Paleogene, not the Miocene. The molluscan fauna of the Paleogene Maéjima Formation contains both Tethyan Indo-Pacific elements and Northern Pacific elements. Taxonomy of selected molluscan taxa including a new arcid, *Arca (Arca) uedai* sp. nov., is described or discussed.

Key words: *Arca (Arca) uedai* sp. nov., First Setouchi Series, Maéjima Formation, molluscan fauna, Paleogene

Introduction

The First Setouchi (or Setouti) Series (Kasama and Huzita, 1957) is the generic name for the Miocene strata scattered in the median zone of southwestern Japan (or the Setouchi Geologic Province; Ikebe, 1957), and all of its constituent formations had been regarded as uppermost lower to lower middle Miocene mainly on the basis of the lithology, sedimentary cycle and molluscs (e.g. Huzita, 1962; Itoigawa and Shibata, 1973, 1986, 1992; Ishida, 1979). It has been known that the “Miocene” molluscan assemblages in the coastal area of the eastern Seto Inland Sea (= Setouchi-Éngan Belt; Yano *et al.*, 1995a) are different from those in the neighboring backbone area (= Bihoku Belt; Yano *et al.*, 1995a), both in the western Setouchi Geologic Province (e.g. Huzita, 1962; Itoigawa, 1969, 1971, 1983; Ueda, 1991; Yano *et al.*, 1995a). There are two current interpretations explaining this difference; some paleontologists have postulated the existences of different water masses in the two areas in the late early to early middle Miocene (e.g. Itoigawa, 1983), while others have assumed a paleogeographic barrier between the two areas in the late early to early middle Miocene except during times of maximum transgression (e.g. Ueda, 1991; Takayasu

et al., 1992; Yano *et al.*, 1995a).

On the other hand, it is becoming clear that constituent formations of the First Setouchi Series around the eastern part of the Seto Inland Sea are of Eocene to Oligocene, not Miocene age, as a result of studies during the last fifteen years (Matsuo, 1987; Ozaki and Matsuura, 1988; Suzuki *et al.*, 1995; Ozaki *et al.*, 1996; Yamamoto *et al.*, 2000b; Kurita *et al.*, 2000, 2001). Yamamoto *et al.* (2000b) found latest middle to late Eocene calcareous nannofossils and dinoflagellate cysts from the “Miocene” Iwaya Formation of the Kobe Group in Awajishima Island, and considered that the difference between the “Miocene” molluscan assemblages in the coastal area of the eastern Seto Inland Sea and those from the backbone area in the western Setouchi Geologic Province is due to chronologic difference. However, their opinion conflicts with the previous molluscan data because the Miocene species have often been listed from the First Setouchi Series in the eastern part of the Seto Inland Sea (Huzita, 1962; Saito, 1962; Saito *et al.*, 1970; Bando and Furuichi, 1978; Itoigawa, 1983; Huzita and Maeda, 1984; Mizuno *et al.*, 1990; Okumura and Sato, 1999). However, most of these studies are unaccompanied by either figures or descriptions of molluscan taxa. Thus, it is necessary to reinvestigate the molluscan

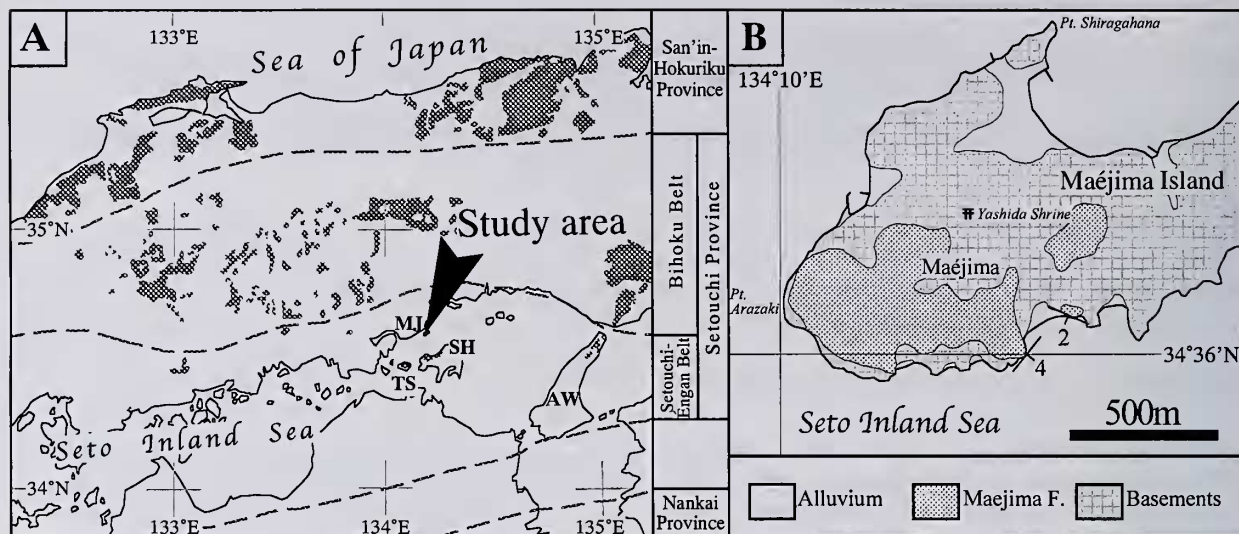


Figure 1. Location and geologic maps of the study area. A. Location of study area (arrow) and distribution of the "Miocene" sediments (hatched area; modified from Shibata and Itoigawa, 1980). The geologic province division follows Yano *et al.* (1995a) partly modified after Seto *et al.* (2000). AW: Awajishima Island, MJ: Maéjima Island, SH: Shodoshima Island, TS: Teshima Island. B. Geologic map of the western part of Maéjima Island, Okayama Prefecture.

fauna of the area, especially from the taxonomical point of view.

The Maéjima Formation is the Tertiary in the western part of Maéjima Island, Ushimado Town, Oku County, southeastern Okayama Prefecture (Figure 1A, B), and has been regarded as one of the constituents of the Miocene First Setouchi Series (e.g. Itoigawa, 1969, 1983; Itoigawa and Shibata, 1986). The distribution of the Tertiary in this island was for the first time reported by Sato (1938), and the stratigraphy was established recently by Yamamoto (2001). Although molluscan assemblages resembling those from other "Miocene" formations in the coastal areas in the eastern part of the Seto Inland Sea have been reported by Itoigawa (1969, 1971, 1983) and Yamamoto (2001) provisionally, precise constituents and faunal characteristics still remain unclear. In this paper, I taxonomically review the molluscan fauna of the "Miocene" Maéjima Formation and discuss the geologic age and its paleogeographical and paleozoogeographical implications.

Geological setting

The Maéjima Formation (Itoigawa and Shibata, 1986, as Maeshima Formation; revised by Yamamoto, 2001) is distributed in the southwestern part of Maéjima Island, unconformably overlying the pre-Tertiary plutonic rocks (Figures 1B, 2). Although Yamamoto (2001) subdivided the Maéjima Formation into the Lower Conglomerate and Sandstone and the Upper Sandstone Member, they are

treated herein as the lower and the upper part with a revision of the boundary (Figure 2A).

The lower part of the Maéjima Formation is less than 10 m in thickness and is composed mainly of granule to pebble conglomerate with numerous fragments of balanids, brachiopods, calcareous algae and molluscs. This part is well exposed on the southwestern coast of Maéjima Island, which is designated to be the type locality of the formation.

The upper part (30 m+) consists mainly of siltstone to muddy very fine-grained sandstone and is associated with calcareous medium- to coarse-grained sandstone. The upper part abuts on the basement and is conformably underlain by the lower part. Outcrop of the upper part is little exposed because it is distributed only in the hilly area with a low relief.

The age of the Maéjima Formation is not known precisely, which indicates an age of Yamamoto *et al.* (2000a) preliminarily reported a Sr isotope value of about 0.7077, which indicates an age of late Eocene or older.

Material

Molluscan samples were collected from eight localities; five from the lower part and three from the upper part (Figure 2A, B). The preservation of fossil molluscs is quite poor and shell material of most specimens examined was dissolved away except for pectinids and an ostreid. Thus, hydrophilic vinyl polysiloxane impression materials (PROVIL novo, Putty®, regular set, Heraeus Kulzer, Inc.,

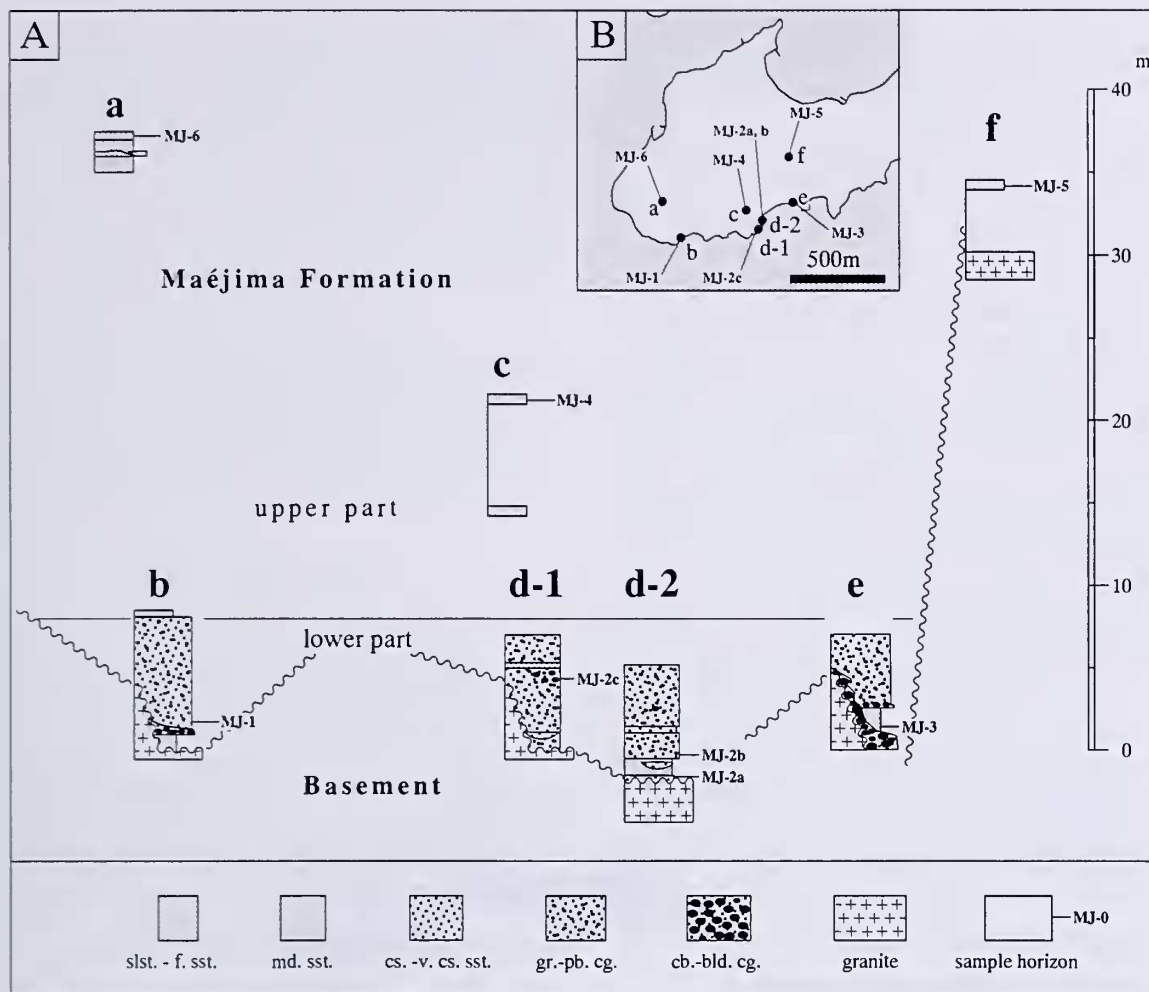


Figure 2. Columnar sections of the Maéjima Formation and locations of measured points and fossil localities. **A.** Columnar sections of the Maéjima Formation. Abbreviations. slst.: siltstone; sst.: sandstone (f.: fine-grained; m.: medium-grained; cs.: coarse-grained; v.cs.: very coarse-grained); cg.: conglomerate (gr.: granule; pb.: pebble; cb.: cobble; bld.: boulder). **B.** Map showing the points where the geologic columns (a through f) were made and fossil localities. Mapped area same as Figure 1B.

Ltd. and EXAFINE® Putty Type, GC Co., Ltd.) were used for the examination of molds.

Molluscan fauna

Four species of Gastropoda and 14 species of Bivalvia including a new species were discriminated as a result of the examination (Table 1). On the basis of the dominant and associated species, the following two assemblages are discriminated (Figure 3).

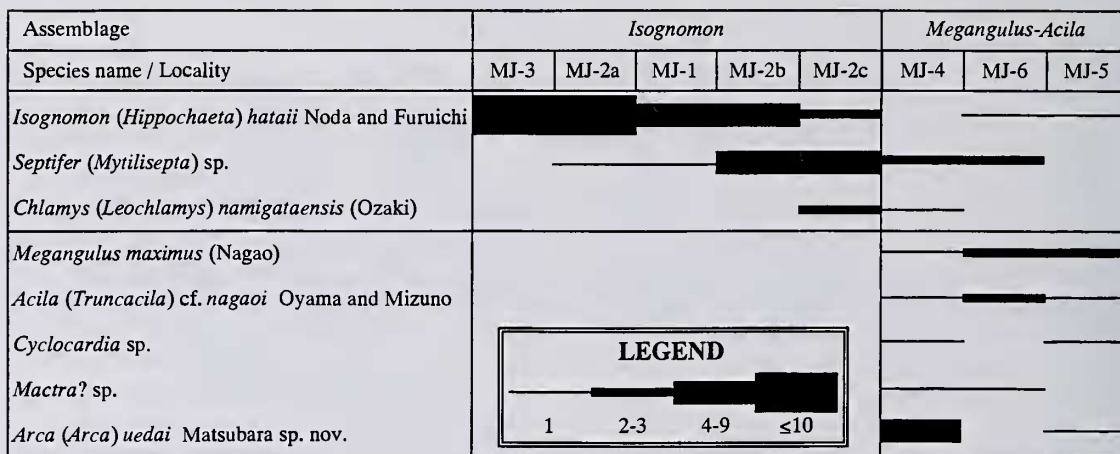
A. *Isognomon* assemblage

This assemblage is characterized by an abundant occurrence of *Isognomon* (*Hippochaeta*) *hataii* Noda and Furuichi, and is generally associated with a few specimens

of *Septifer* (*Mytilisepta*) sp. The *Isognomon* assemblage occurred from conglomerate to conglomeratic sandstone in the lower part of the Maéjima Formation (Locs. MJ-1, 2a, 2b, 2c and 3). At Loc. 3, *I. (H.) hataii* occurs abundantly in the matrix of boulder conglomerate without any associated species, and most of the specimens are articulated. At other localities, although most specimens of this species are disarticulated, they are less broken and a few articulated valves are included. Consequently, this assemblage is regarded to be autochthonous or para-autochthonous in broad sense. Taking the lithology of rocks in which the assemblage occurs and the habitat of the Recent homologues of these two species into account (Higo *et al.*, 1999), this assemblage inhabited littoral to upper sublittoral, gravelly to rocky bottom of an open sea.

Table 1. List of fossil Mollusca from the "Miocene" Maéjima Formation.

Horizon	Lower part					Upper part		
	MJ-1	MJ-2a	MJ-2b	MJ-2c	MJ-3	MJ-4	MJ-5	MJ-6
Gastropoda								
Patellogastropoda, fam., gen. et sp. indet.								1
<i>Calyptrea</i> sp.						2		1
Naticidae? gen. et sp. indet.								1
Muricidae? gen. et sp. indet.						1		
Bivalvia								
<i>Acila (Truncacila)</i> cf. <i>nagaoi</i> Oyama and Mizuno						1	1	2
<i>Arca (Arca)</i> <i>uedai</i> sp. nov.						6	1	
<i>Glycymeris (glycymeris)</i> sp.								1
<i>Septifer (Mytilisepta)</i> sp.	1	1	3	4		2		2
<i>Isognomon (Hippochaeta)</i> <i>hataii</i> Noda and Furuichi	6	12	4	2	26		1	1
<i>Delectopecten</i> sp.								1
<i>Chlamys (leochlamys)</i> <i>namigataensis</i> (Ozaki)				2		1		
<i>Crassastrea</i> sp.			1					
Luchinidae gen. et sp. indet.						1		1
<i>Cyclocardin</i> sp.						1	1	
<i>Glans</i> sp.								2
<i>Megangulus maximus</i> (Nagano)						1	3	3
<i>Mactra?</i> sp.						1		3
<i>Tapes?</i> sp.								2
TOTAL	7	13	8	8	26	17	7	21

**Figure 3.** Molluscan assemblages of the Maéjima Formation. Number in legend indicates that of individuals.

The *Ostrea-Balanus* assemblage of Itoigawa (1969) probably corresponds to the *Isognomon* assemblage. But only a single specimen of *Crassostrea* sp. was collected from Loc. MJ-2c among all the localities examined in the present study. Consequently, the occurrence of the *Ostrea-Balanus* Assemblage from the Maéjima Formation is not supported.

B. *Megangulus-Acila* assemblage

The *Megangulus-Acila* assemblage occurred from siltstone to medium-grained sandstone in the upper part of

the Maéjima Formation (Locs. MJ-4, 5 and 6). This assemblage is characterized by infaunal Bivalvia species, *Megangulus maximus* (Nagao) and *Acila (Truncacila)* cf. *nagaoi* Oyama and Mizuno. Most shells of these species are disarticulated and are arranged parallel to the bedding plane. However, a few articulated specimens of *M. maximus*, *A. (T.) cf. nagaoi*, *Cyclocardia* sp. and *Mactra?* sp. are recognized. This fact indicates that most shells of these species have not been transported a great distance from their original habitat. These species are regarded as shallow burrowers in an upper sublittoral, muddy to sandy

bottom (Higo *et al.*, 1999). On the other hand, *Arca* (*Arca*) *uedai* sp. nov., *Septifer* (*Mytilisepta*) sp. and *Isognomon* (*Hippochaeta*) *hataii* are considered to be epibyssate benthos on a gravelly to rocky bottom. There are no articulated specimens among these species, and thus they are considered to have been transported from their original habitat. These facts suggest that this assemblage represents a mixed composition formed in an upper sublittoral, muddy to muddy sand bottom neighboring a rocky shore in an open sea.

The occurrences of muddy to sandy bottom elements such as *Acila* (*Truncacila*), *Mactra*? and *Cyclocardia* indicate that this assemblage is compared with the *Mactra-Acila* assemblage of Itoigawa (1983) characterizing the molluscan assemblages in the coastal area of the eastern Seto Inland Sea.

Discussion

Geologic age

Among the constituents of the molluscan fauna of the Maéjima Formation, *Megangulus maximus* (Nagao), *Isognomon* (*Hippochaeta*) *hataii* Noda and Furuichi, and *Chlamys* (*Leochlamys*) *namigataensis* (Ozaki) are important for the age estimation (Figure 4). The first species has been recorded from the Paleogene of Kyushu and the other two species are known from the "Miocene" of southwest Honshu around the eastern part of the Seto Inland Sea.

M. maximus occurs from the Funazuan to the Nishisonogian Stages (Mizuno, 1962) of southwest Japan (e.g. Nagao, 1928b; Oyama *et al.*, 1960; Mizuno, 1964; Okamoto and Imamura, 1964; Okamoto, 1970; Shuto and Shiraiishi, 1971; Kamada, 1980; Fuse and Kotaka, 1986; Shuto, 1991). Although the precise age of the stratotype of the Funazuan Stage, the Funazu Sandstone Member of the Iojima Formation in the Takashima Coalfield, west Kyushu, is unknown, a calcareous nannofossil biostratigraphy of the correlate Matsushima Group in the Sakito-Matsushima Coalfield (SK-MT in Figure 4) was studied by Okada (1992). Okada (1992) assigned this group to the Subzone CP 15b to CP 16a of Okada and Bukry (1980). In addition, Okada (1992) also correlated the Oniike Formation of the Sakasegawa Group in the Amakusa Coalfield (AM in Figure 4) and the Yotsuyama Formation of the Manda Group in the Miike Coalfield (MK in Figure 4), both of which are referred to the Okinoshiman Stage below the Funazuan Stage (Mizuno, 1964), to CP 14b to CP 15b. These calcareous nannofossil biostratigraphic data suggest that the lower limit of the Funazuan Stage is in CP 15b. According to Berggren *et al.* (1995), this calcareous nannofossil zone ranges from 36.0 to 34.3 Ma or the late Eocene. Okada (1992) also studied the age of the Nishisonogi Group in the Sakito-Matsushima Coalfield

(SK-MT in Figure 4), the stratotype of the Nishisonogian Stage by means of calcareous nannofossil biostratigraphy, and assigned the age of the upper part of the Nishisonogi Group to sometime during CP 17 to CP 19 on the basis of the occurrence of *Dictyococcites bisectus*. According to Berggren *et al.* (1995), the last occurrence of this species (cited as *Reticulofenestra bisecta* in Berggren *et al.*, 1995) is 23.9 Ma or the latest Oligocene. Concerning the Ashiya Group in the Chikuho Coalfield (CH in Figure 4), one of the correlatives of the Nishisonogian Stage, biostratigraphic studies were carried out by Saito and Okada (1984), Tsuchi *et al.* (1987), Okada (1992) and Ibaraki (1994). According to them, the age of the Ashiya Group is the late early to early late Oligocene. Further, the Taoyama Formation of the Hioki Group in the Yuyawan area (YY in Figure 4), another correlative of the Nishisonogian Stage, contains *D. bisectus* (Fuse and Kotaka, 1986). Ozaki (1999) also reported fission-track ages of 25.2 ± 1.7 Ma and 23.1 ± 1.6 Ma (error: 1σ) from the Hitomaru Formation which overlies the Taoyama Formation in the Yuyawan area. Taking these data into account, the range of *M. maximus* is regarded as late Eocene to Oligocene (Figure 4).

I. (H.) hataii is a species originally described from the "Miocene" Teshima Formation of the Tonosho Group in Teshima Island, northern Kagawa Prefecture (SH-TS in Figure 4; Noda and Furuichi, 1972). Bando and Furuichi (1978) correlated this formation to the Shikai Formation of the Tonosho Group in Shodoshima Island, situated several kilometers east of Teshima Island. This correlation is strongly supported by the occurrence of an endemic bivalve, *Tapes nagahamaensis* Saito, Bando and Noda, 1970, recorded only from the Teshima and Shikai Formations. Saito *et al.* (1970), Noda and Furuichi (1972), Bando and Furuichi (1978), Itoigawa and Shibata (1992) and Okumura and Sato (1999) all regarded the Tonosho Group distributed in Shodoshima and Teshima Islands as of early middle Miocene age. However, Kurita *et al.* (2000) reported the Eocene dinoflagellate cysts from the Shikai Formation. Consequently, the age of the Teshima Formation, which contains *I. (H.) hataii*, is also considered to be Eocene (Figure 4).

C. (L.) namigataensis was originally described from the "Miocene" Namigata Formation in Ibara City, Okayama Prefecture (NM in Figure 4; Ozaki, 1956). The age of the Namigata Formation has been considered to be the lowest middle Miocene (e.g. Shibata and Itoigawa, 1980; Itoigawa, 1983; Yano *et al.*, 1995a, b). Yano *et al.* (1995b) discriminated four benthic foraminiferal assemblages characterized by such species as *Elphidiella momiyamaensis* Uchio, *Pseudononion japonicum* Asano, *Hanzawaia tagaensis* Asano and *Cibicoides pseudoungerianus* (Cushman) from the Namigata Formation. They pointed out that these assemblages are comparable with

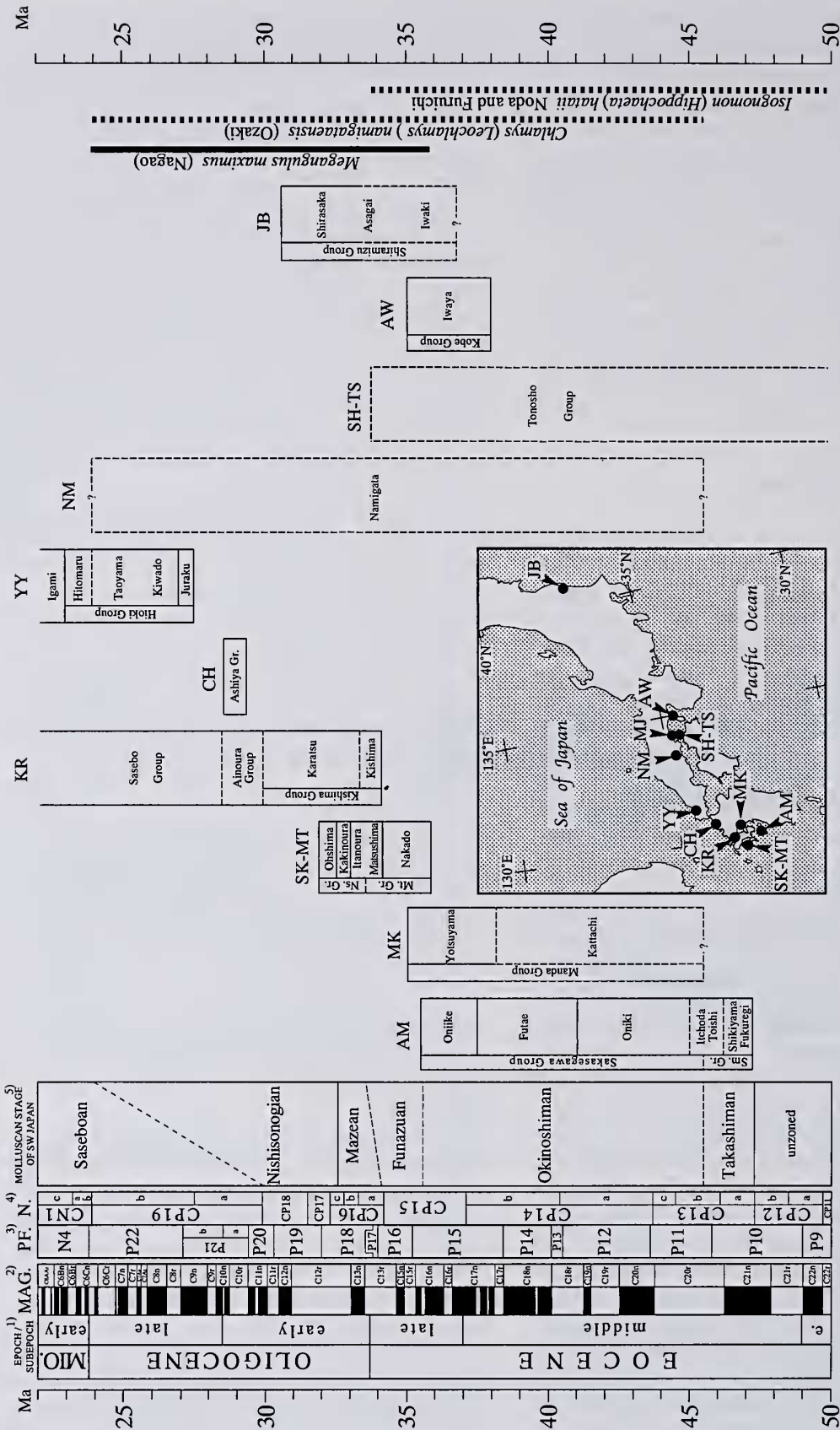


Figure 4. Correlation of the selected Paleogene strata in Japan and chronologic range of molluscan species discussed in the text. Time scale: 1) Berggren *et al.* (1995); 2) Cande and Kent (1995) and Berggren *et al.* (1995); 3) Blow (1969); 4) Okada and Bukry (1980); 5) Mizuno (1962, 1964). e.: early; MAG.: Magnetic polarity; MIO.: Miocene; N.: Calcareous nannofossils; PL.: Planktonic foraminifera. AM: Amakusa Coalfield (Okada, 1992); AW: Awajishima area (Yamamoto *et al.*, 2000b); CH: Chikugo Coalfield (Saito and Okada, 1984; Tsuchi *et al.*, 1987; Okada, 1992; Ibaraki, 1994); JB: Joban Coalfield (Tomida, 1986; Yanagisawa and Suzuki, 1987); KR: Karatsu Coalfield (Sakai *et al.*, 1990; Miyachi and Sakai, 1991; Okada, 1992; Ibaraki, 1994); MK: Miike Coalfield (Okada, 1992); NM: Namigata area (Nishimoto and Itoigawa, 1977; SH-TS: Shidoshima-Teshima area (Kurita *et al.*, 2000); SK-MT: Sakito-Matsushima Coalfield (Okada, 1992); YY: Yuyawan area (Fuse and Kotaka, 1986; Ozaki, 1999). Mt.Gr.: Matsushima Group; Ns.Gr.: Nishisonogi Group; Sm.Gr.: Shimoshima Group.

those of the *Miogypsina kotoi-Operculina complanata* Assemblage Zone of Nomura (1992), being assigned to the latest early to early Middle Miocene. However, *E. momiyamaensis*, *H. tagaensis* and *C. pseudoungerianus* were also reported from the Iwaya Formation of the Kobe Group by Tai (1959), from which Yamamoto *et al.* (2000b) reported Eocene calcareous nannofossils and dinoflagellate cysts. In addition, the benthic foraminiferal assemblages from the Namigata Formation do not include *Ammonia tochiensis* (Uchio) which is one of the representative species in the Miocene benthic foraminiferal zone (Yano *et al.*, 1995b). Consequently, the benthic foraminiferal data do not indicate a Miocene age for the Namigata Formation.

On the other hand, Nishimoto and Itoigawa (1977) preliminarily reported *Carcharodon angustidens* (Agassiz) from the Namigata Formation in addition to the upper lower Oligocene Yamaga Formation of the Ashiya Group and the upper Oligocene Taoyama Formation of the Hioki Group. This fossil shark has very characteristic teeth with distinct anterior and posterior cusps. Yabumoto and Uyeno (1994) indicated that in Japan *C. angustidens* has been restrictedly found from the middle Eocene to the upper Oligocene of southwest Japan. Consequently, the age of the Namigata Formation is regarded to be somewhere during the middle Eocene to the late Oligocene, not the Miocene (Figure 4).

Although *C. (L.) namigataensis* was also recorded from the middle Miocene Kawazu Formation in Shimane Prefecture by Masuda (1962), his figured specimen (Masuda, 1962, pl. 21, fig. 1) is not referred to *Pecten (Chlamys) namigataensis* Ozaki, 1956 (see systematic paleontology to be discussed below). Recently, *C. (L.) namigataensis* was for the first time found from the Paleogene Iwaki Formation of the Shiramizu Group in the Joban Coalfield (JB in Figure 4), northeast Honshu, Japan. Nemoto and O'Hara (2001) figured a right valve of *Chlamys ashियाensis* (Nagao) from this formation, but their figured specimen is, in my opinion, *C. (L.) namigataensis* (see systematic paleontology). The age of the Iwaki Formation of the Shiramizu Group is considered to be the late Eocene or the early Oligocene on the basis of the occurrence of *Entelodon cf. orientalis* Dashzeveg (Tomida, 1986) and the planktonic microfossils age of the Shirasaka Formation (early Oligocene; Yanagisawa and Suzuki, 1987), the uppermost constituents of the Shiramizu Group.

Taking these facts into account, the geologic age of the Maéjima Formation is judged to be Paleogene, somewhere between the middle Eocene and late Oligocene.

Implications of the molluscan fauna of Maéjima Formation

Itoigawa (1983) grouped the "Miocene" molluscan as-

semblages from the First Setouchi Series in the coastal area of the eastern part of the Seto Inland Sea, including the Maéjima Formation, into four types, the *Cyclina-Barbatia*, the "*Ostrea*", the *Macra-Acila* and the *Cyclocardia-Nuculana* assemblages. Constituents of these assemblages were considered to have inhabit the intertidal to uppermost sublittoral sandy mudbottom, uppermost to upper sublittoral rocky bottom, upper sublittoral sandy bottom, and upper sublittoral muddy bottom, respectively (Itoigawa, 1983). An assemblage comparable in generic composition to the *Macra-Acila* assemblage was also recognized in the Maéjima Formation, namely, the *Megangulus-Acila* assemblage. Recent studies on planktonic microfossils (Kurita *et al.*, 2000, 2001; Yamamoto *et al.*, 2000b) indicate that some of the formations yielding these assemblages are of Eocene age, which concurs with the results of the present study for age assignment.

It has been known that the four assemblages of Itoigawa (1983) have little similarity in not only specific but also generic compositions to the Miocene molluscan assemblages from the neighboring backbone area (e.g. Huzita, 1962; Itoigawa, 1969, 1971, 1983; Ueda, 1991; Yano *et al.*, 1995a). The latter assemblages are represented by the embaymental arcid-potamid [potamidid] fauna of Tsuda (1965). Yamamoto *et al.* (2000b) preliminarily considered that the difference between the assemblages from the coastal area of the Seto Inland Sea and those from the backbone area is chronological taking account of the Eocene planktonic microfossils from the Iwaya Formation of the Kobe Group, while previous researchers explained it by paleoenvironmental or paleogeographic factors in Miocene time (e.g. Itoigawa, 1983; Ueda, 1991; Takayasu *et al.*, 1992; Yano *et al.*, 1995a). The result of the present study supports the view of Yamamoto *et al.* (2000b), and both indicate that the Miocene First Seto Inland Sea (Ikebe, 1957) was not invaded in the coastal area of today's eastern part of the Seto Inland Sea, and that the "Miocene" shallow marine area in the eastern part of the Seto Inland Sea in the judgment of previous researchers (e.g. Shibata and Itoigawa, 1980; Itoigawa and Shibata, 1992; Takayasu *et al.*, 1992) was in fact of Paleogene age. Consequently, it is necessary to revise the Tertiary paleogeography of southwest Japan on the basis of the precise geochronologic data in near future.

It is notable that the molluscan fauna of the Paleogene Maéjima Formation contains both Tethyan Indo-Pacific elements and Northern Pacific elements of Honda (1991, 1994). The former are represented by such genera as *Isognomon* and *Septifer*, and the latter by, for example, *Cyclocardia* and *Megangulus* (Honda, 1994; Ogasawara, 1996). Honda (1994) revealed the northward migration of the Tethyan Indo-Pacific elements in the middle Eocene and the southward migration of the Northern Pacific ele-

ments during the late early Oligocene to early Miocene. However, the precise timing and mode of migration of the molluscan fauna have not fully been clarified because Paleogene shallow marine sediments were accepted to be almost lacking in the area between Kyushu and the Pacific coast of northeast Honshu. Although the precise geologic age of the Maéjima Formation was not determined by the molluscan evidence in the present study, further geochronological studies of the Paleogene shallow marine sediments in the coastal area of the eastern part of the Seto Inland Sea and taxonomical studies of the molluscan fauna will provide a reliable basis for elucidation of the successive changes of the Paleogene molluscan fauna in the Northwest Pacific region.

Concluding remarks

Until the middle of 1990s, Paleogene marine sediments in southwest Japan had been considered to be restricted mostly to the Southern Shimanto Belt (Taira *et al.*, 1980) in the back arc of the Japanese Islands, except for Kyushu. Honda (1991, 1994) discriminated the North Japan-Western Okhotsk, Central Japan and Taiwan-South Japan Provinces from north to south for the western Pacific Paleogene molluscan faunal provinces. The Central Japan Province, in particular, was proposed on the basis of fragmental molluscan records from the accretionary sediments deposited in the lower sublittoral zone or at greater depths. Consequently, the characteristics of the shallow marine molluscan faunas in this province have been less than clear. The result of the present study strongly supports the age estimation based on planktonic microfossils by Kurita *et al.* (2000, 2001) and Yamamoto *et al.* (2000b) that the constituent formations of the "Miocene" First Setouchi Series in the coastal area of the eastern part of the Seto Inland Sea are in fact Paleogene, not Miocene (Kurita *et al.*, 2000, 2001; Yamamoto *et al.*, 2000b).

Systematic description of selected taxa

All the illustrated specimens are housed at the Museum of Nature and Human Activities, Hyogo (MNHAH). The following institutional abbreviations are also used in this paper: IGPS: Institute of Geology and Paleontology, Tohoku University, Sendai; NSMT: National Science Museum, Tokyo; UMUT: University Museum, the University of Tokyo.

Class Bivalvia
Subclass Paleotaxodonta
Order Nuculoida
Superfamily Nuculoidea
Family Nuculidae

Genus *Acila* H. & A. Adams, 1858
Subgenus *Truncacila* Grant and Gale, 1931,
ex Schenck MS

Acila (Truncacila) sp. cf. *A. (T.) nagaoui*
Oyama and Mizuno, 1958

Figure 5.4

Compare.—

Acila nagaoui Mizuno (MS). Mizuno, 1956, pl. 2, fig. 1.
{*nomen nudum*}

Acila (Truncacila) nagaoui Oyama and Mizuno, 1958, p. 7–8,
pl. 1, figs. 14, 15.

Material.—MNHAH reg. no. D1-018895 (from MJ-5).

Discussion.—The specimens from the Maéjima Formation are comparable with *Acila (Truncacila) nagaoui* Oyama and Mizuno, 1958, in having a small, rather longer than high, posteriorly oblique, oval shell with a beak situated at four-fifths of the shell length from the anterior end and a weak posterior ridge. They are not sufficiently well preserved to allow a precise species assignment.

Subclass Pteriomorphia
Order Arcoidea
Superfamily Arcoidea
Family Arcidae
Subfamily Arcinae
Genus *Arca* Linnaeus, 1758
Subgenus *Arca* Linnaeus, 1758

Arca (Arca) uedai sp. nov.

Figure 5.5, 5.7a-c, 5.12

Type specimens.—MNHAH reg. nos. D1-018896 (Holotype); D1-018897 through D1-018903 (Paratypes).

Type locality.—Loc. MJ-4. A small outcrop exposure on its northern side about 400m south-southeast of Yoshida Shrine, Maéjima Island, Ushimado Town, Oku County, Okayama Prefecture (34° 36' 2" N, 134° 10' 29" E).

Diagnosis.—Rather small-sized *Arca (Arca)* with a low umbonal area, low crescent-shaped ligamental area, narrow hinge plate and shell surface sculptured by fine, low, numerous radial ribs.

Description.—Shell rather small (less than 40 mm in shell length), transversely elongate quadrate, inequilateral, moderately inflated; hinge line straight, long; beak blunt, prosocline, situated about two-fifths anteriorly of shell length; posterior ridge distinct, shell strongly depressed behind it; posteroventral margin obliquely truncated; central part of shell weakly depressed; shell surface sculptured by about 60 fine, low radial ribs; ribs generally with a fine intercalary rib on interspace; growth lines fine, generally

Table 2. Measurements of *Arca (Arca) uedai* sp. nov.

MNHANreg.no.	Length (mm)	Height (mm)
D1-018896*	34.2	18.8
D1-018897**	24.5***	12.3***
D1-018898**	35.0+***	15.2***
D1-018899**	30.9+	15.9

*holotype. **paratype. ***deformed

weak but rather strengthen on central depressed area; ligamental area low crescentic in shape, smooth except for one or a few, rather deep, chevron-shaped ligamental grooves; adductor muscle scars moderate in size, ovate (type A of Noda, 1966), weakly impressed; pallial line shallow, weakly impressed; inner ventral margin not crenated.

Etymology.—The present new species is named in honor of the late Tetsuro Ueda of Niigata University, who contributed to the molluscan paleontology of the First Setouchi Series during the middle 1980s to early 1990s.

Discussion.—*Arca (Arca) uedai* sp. nov. closely resembles *A. (A.) miurensis* Noda, 1966, from the Pleistocene Koshiba Formation in Kanagawa Prefecture. However, the present new species possesses a narrower hinge plate and lower ligamental area.

A. (A.) sakamizuensis Hatai and Nisiyama, 1952, from the Oligocene Sakamizu Formation of the Ashiya Group in Fukuoka Prefecture, Kyushu, is similar to the present new species in having fine radial ribs. The former is discriminated from the latter by having a more produced umbonal area and a higher ligamental area.

A. (A.) washingtoniana Dickerson, 1917, from the Oligocene Gries Ranch Formation of Washington, U.S.A., is another allied species, but is distinguished from *Arca (Arca) uedai* sp. nov. by having coarser radial ribs on the younger shell and stronger teeth.

The Recent *A. (A.) boucardi* Jousseume is easily distinguished by having a larger shell with a stronger posterior ridge, coarser, less numerous radial ribs, and a higher umbonal area.

Measurements.—Table 2.

Order Mytiloida
Superfamily Mytiloidea
Family Mytilidae
Genus *Septifer* Récluz, 1848
Subgenus *Mytilisepta* Habe, 1951

Septifer (Mytilisepta) sp. indet.

Figure 5.8, 5.9, 5.14

Material.—MNHAH reg. nos. D1-18905 through D1-018907 (from MJ-2b), D1-018908 and D1-018909 (from

MJ-2c), D1-018910 (from MJ-4), and D1-018911 (from MJ-6).

Discussion.—Several poor specimens have been obtained. The occurrence of a septum in the subumbonal region and inner ventral margin lacking fine crenations indicate this species is referred to the subgenus *Mytilisepta* Habe, 1951.

Septifer (Mytilisepta) sp. from the Maéjima Formation is similar in general shell shape to *Septifer (Septifer) nagaoui* Oyama, 1951, which was introduced as a new name for *Mytilus hirsutus* Lamarck of Yokoyama, 1927 from the Oligocene Nishisonogi Group in Nagasaki Prefecture. However, the holotype designated by Oyama (1951) (UMUT reg. no. CM24987) has a very finely crenated inner ventral margin, as Mizuno (1952) described.

The present species is easily distinguished from the Recent species, *Septifer (Mytilisepta) keenae* Nomura, 1936 distributed in southern Hokkaido and southward, in having a larger shell with finer radial ribs and weakly curved anteroventral margin.

Order Pterioida
Superfamily Pterioidea
Family Isognomonidae
Genus *Isognomon* [Lightfoot, 1786]
Subgenus *Hippochaeta* Philippi, 1844

Isognomon (Hippochaeta) hataii
Noda and Furuichi, 1972

Figures 5.15-5.17, 6.13, 6.14

Isognomon (Isognomon) hataii Noda and Furuichi, 1972, p. 120, text-fig. 1.

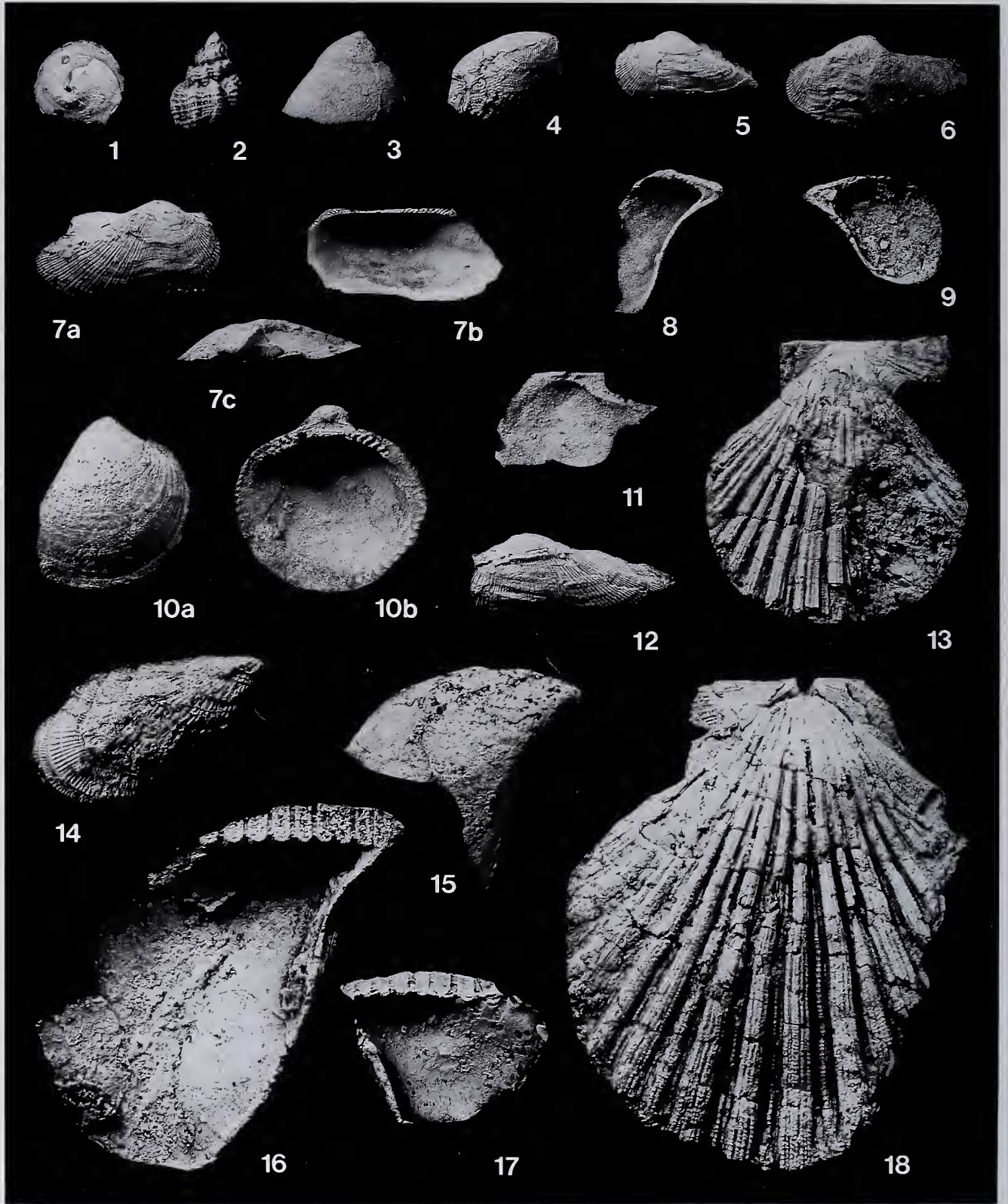
Isognomon (Isognomon) hataii Noda and Furuichi, Kaikiri and Nishimoto, 1995, p. 204.

Type specimen.—IGPS coll. cat. no. 91766 (Holotype).

Material.—MNHAH reg. nos. D1-018912 through D1-018918 (from MJ-1), D1-018919 through D1-018924 (from MJ-2a), D1-018925 through D1-018941 (from MJ-3), and D1-018942 (from MJ-6).

Emended diagnosis.—Shell of large size, mytiliform, rather thin except for ligamental area, moderately inflated; shell surface nearly smooth except for very fine, irregular, dense growth lines; byssal sinus roundly depressed; ligamental part rather thick; ligamental area rather broad, with 8 to 12 deeply concave resilifer grooves; lamellar ligament attachment area broader than groove, weakly depressed, surrounded by a fine ridge.

Description.—Shell rather large in size for the genus, mytiliform, rather thin except for ligamental area, moderately inflated; apical angle about 60°; byssal sinus rather depressed; posterodorsal margin nearly straight or weakly



curved; posteroventral margin nearly parallel to anterior one, weakly curved; centroventral margin arcuate and smoothly continuing to antero- and posteroventral margin; shell surface nearly smooth, sculptured only by very fine, irregular, dense growth lines; ligamental part thick; ligamental area rather broad, weakly annulated, with 8 to 12 resilifer grooves on fully grown individuals; resilifer grooves subequal, perpendicular to posterodorsal margin; lamellar ligament attachment areas weakly depressed, broader than resilifer grooves, surrounded by a fine ridge, with U-shaped inner margin; three byssal-pedal retractor muscle scars on sublignamental part of internal shell; pallial line shallow, coarse, irregularly dotted near beak; adductor muscle scar indistinct.

Discussion.—The broad and shallow lamellar ligament attachment areas, narrow resilifer grooves and three byssal-pedal retractor muscle scars on the inner dorsal area indicate the Maéjima specimens are referred to the subgenus *Hippochaeta*. The ligamental area of the type species, *Perna maxillata* Lamarck, is well figured in Cox (1969) and Savazzi (1995).

The examined specimens from the Maéjima Formation can be referred to *Isognomon* (*Isognomon*) *hataii* Noda and Furuichi, 1972. This species was originally described from the Teshima Formation of the Tonosho Group in Teshima Island, Kagawa Prefecture, on the basis of a single incomplete left valve. Unfortunately, the shell features such as shape, thickness and surface sculpture are unknown because the holotype (IGPS coll. cat. no. 91766) is an internal mold lacking both shell material and the posterior half of the ventral area. Comparison with the holotype shows that apical angle and ligamental features are identical. Consequently, *I. (I.) hataii* is transferred here to the subgenus *Hippochaeta*, and the holotype is a fragmental juvenile specimen having less diagnostic characters.

Earlier Matsubara (2001) preliminarily identified *Isognomon* from the Maéjima Formation as *Pedalion murayamai* Yokoyama, 1932, originally described from the "Bed III" (= ? middle Eocene Krasnopoliievskaya Forma-

tion, after Kafanov and Amano, 1997) in the Dorogawa-Hishitori Region, south Sakhalin. However, it becomes clear that the Maéjima specimens have deeper resilifer grooves, less depressed lamellar ligament attachment areas, coarser pallial line, and a much more indistinct adductor muscle scar than *P. murayamai*. In addition, the byssal area of *P. murayamai* is rather distinctly bent, while that of the Maéjima specimens is gently curved. Consequently, the Maéjima specimens are not referred to this species. It may be noted that the holotype of *P. murayamai* (UMUT reg. no. CM27020) is missing.

The present species is also similar in shell shape to *Pedalion tomiyasui* Nagao, 1928a, from the middle Eocene Iojima Formation of the Okinoshima Group of Kyushu. However, it is easily distinguished from the latter species by having a larger shell with narrower resilifer grooves and weakly compressed lamellar ligament attachment areas.

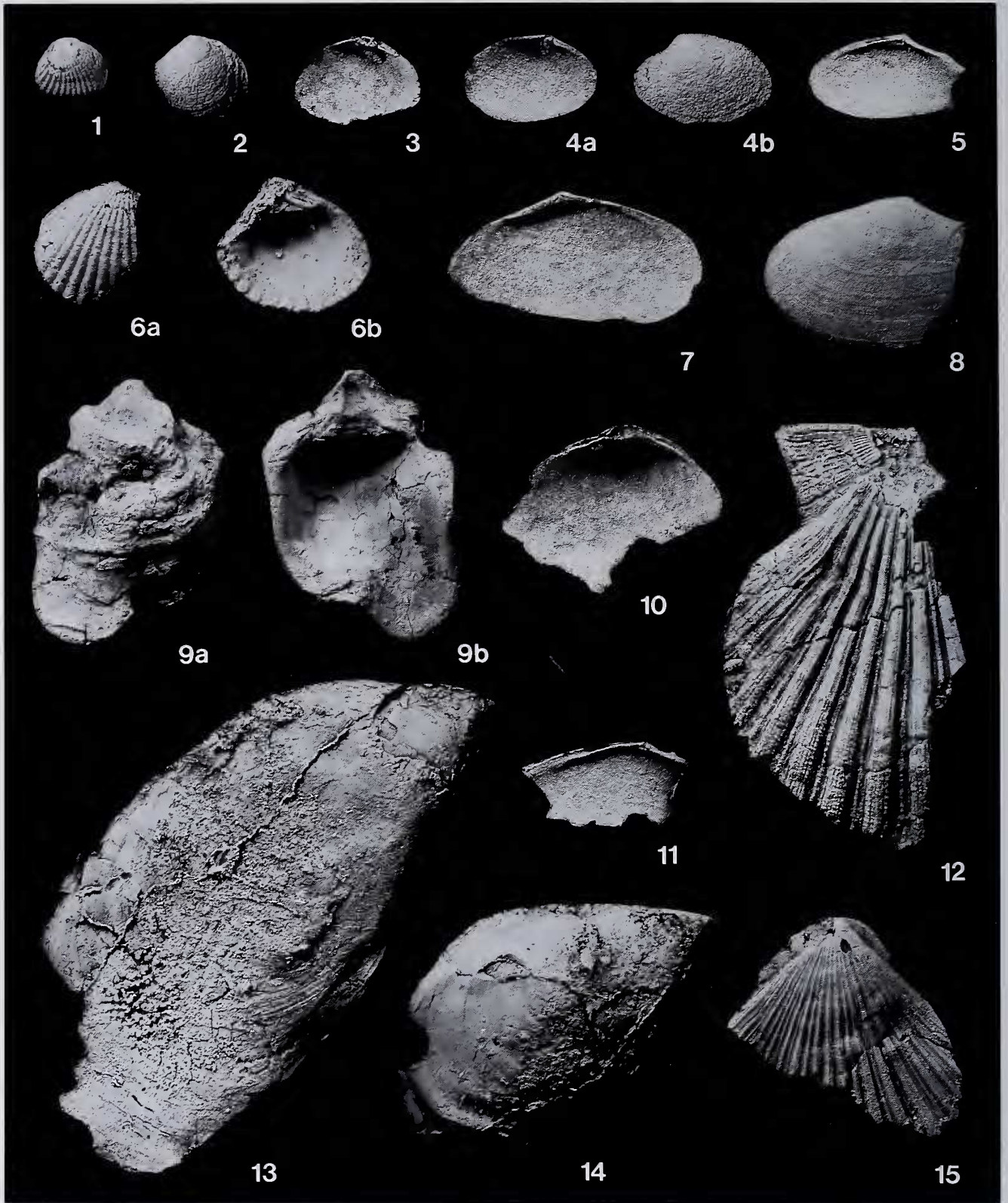
Pedalion clarki Effinger, 1938, originally described from the Oligocene Gries Ranch Formation of Washington, U.S.A., is another allied species, but differs in having more numerous resilifer grooves.

Pedalion tugaruense Nomura, 1935a, originally described from the lower middle Miocene Tanosawa Formation in Aomri Prefecture, northeast Japan, is easily distinguished from *I. (H.) hataii* by its thicker, much more longitudinally elongate shell with higher ligamental area and much blunter umbonal angle.

Distribution.—Teshima Formation of the Tonosho Group in Kagawa Prefecture, Eocene; Maéjima Formation in Okayama Prefecture, Eocene or Oligocene.

Order Ostreoida
Superfamily Pectinoidea
Family Pectinidae
Subfamily Chlamydinae
Tribe Chlamidini
Genus *Chlamys* [Röding, 1798]
Subgenus *Leochlamys* MacNeil, 1967

◆ **Figure 5.** Mollusca from the Maéjima Formation (1). All specimens in natural size, unless otherwise stated. All specimens whiten by magnesium oxide. **1.** *Calyptrea* sp. Dorsal view of internal mold, MNHAH reg. no. D1-018890, $\times 1.5$. **2.** Muricidae? gen. and sp. indet. Dorsal view, MNHAH reg. no. D1-018893, silicon rubber cast, $\times 1.5$. **3.** Naticidae? gen. and sp. indet. Dorsal view, rather compressed, MNHAH reg. no. D1-018891, silicon rubber cast, $\times 1.5$. **4.** *Acila* (*Truncacila*) cf. *nagaoui* Oyama and Mizuno. Left valve, MNHAH reg. no. D1-018895, silicon rubber cast. **5, 6, 7a-c, 12.** *Arca* (*Arca*) *uedai* sp. nov. **5.** Left valve, MNHAH reg. no. D1-018897 (paratype). **6.** Left valve, MNHAH reg. no. D1-018899, $\times 1.5$. **7a-c.** Right valve, MNHAH reg. no. D1-018896 (holotype), silicon rubber cast. **7a.** External view. **7b.** Internal view. **7c.** Umbonal view. **12.** Left valve MNHAH reg. no. D1-018898 (paratype), compressed umbonal-ventrally. All specimens silicon rubber casts. **8, 9, 14.** *Septifer* (*Mytilisepta*) sp. **8.** Internal view of left valve, MNHAH reg. no. D1-018911. **9.** Internal view of right valve, MNHAH reg. no. D1-018905. **14.** Right valve, MNHAH reg. no. D1-018908. All specimens silicon rubber casts. **10a-b.** *Glycymeris* (*Glycymeris*) sp. Left valve, MNHAH reg. no. D1-018904, silicon rubber cast. **10a.** External view. **10b.** Internal view showing especially strong teeth and ligamental area with chevron sculpture. **11.** *Delectopecten* sp. Internal view of left valve, MNHAH reg. no. D1-018943, silicon rubber cast, $\times 2$. **13, 18.** *Chlamys* (*Leochlamys*) *namigataensis* (Ozaki). **13.** Right valve, MNHAH reg. no. D1-018945. **18.** Left valve, MNHAH reg. no. D1-018944. **15, 16, 17.** *Isognomon* (*Hippochaeta*) *hataii* Noda and Furuichi. **15.** Right valve lacking ventral part, MNHAH reg. no. D1-018929. **16.** Internal view of left valve, MNHAH reg. no. D1-018926. **17.** Internal view of right valve, showing ligamental area. MNHAH reg. no. D1-018916. All specimens silicon rubber casts.



Leochlamys MacNeil, 1967, p. 9–10.

Azumapecten Habe, 1977, p. 82.

Type species.—*Chlamys* (*Leochlamys*) *tugidakensis* MacNeil, 1967, by original designation. Unnamed "Pliocene" in Tugidak Island, Alaska, U.S.A.

Discussion.—Habe (1977) proposed the subgenus *Azumapecten* on the basis of the following description: "Shell of small to moderate size; right valve rather inflated, with irregular, spiny radial ribs; left valve rather compressed; anterior and posterior auricles intercalating a beak between them, rather large; posterior auricle rather oblique; byssal notch on anterior part of right valve" (translated from Japanese by the present writer). *Pecten* (*Chlamys*) *farreri* Jones and Preston, 1904, living in the Northwest Pacific was designated as the type species.

The original description of *Azumapecten* involves several obscurities in the diagnosis and is not associated with any comparison to allied genera or subgenera. However, many malacologists have treated *Azumapecten* as a valid genus or subgenus (e.g. Habe, 1981; Waller, 1993; Hayami and Matsumoto, 1995; Wang, 1996; Higo *et al.*, 1999; Hayami, 2000).

On the other hand, MacNeil (1967) proposed the subgenus *Leochlamys* which was typified by *Chlamys* (*Leochlamys*) *tugidakensis* MacNeil, 1967. MacNeil (1967) and Sinelnikova (1975) also referred "*Chlamys nipponensis* Kuroda" (= *P. (C.) farreri*) to the subgenus *Leochlamys*. Indeed, the large anterior auricle, deep byssal notch, relatively strong ctenolium, irregular spiny radial ribs on shell surface, shagreen microsculpture at least on interspaces of ribs, and absence of distinct crenulations on the inner ventral margin are common to both subgenera. Consequently, *Azumapecten* Habe, 1977, is a junior synonym of *Leochlamys* MacNeil, 1967.

Chlamys (*Leochlamys*) *namigataensis* (Ozaki, 1956)

Figures 5.13, 5.18, 6.12, 6.15

Pecten (*Chlamys*) *namigataensis* Ozaki, 1956, p. 7–8, pl. 2, fig. 4.

Chlamys (*Minachlamys*) *namigataensis* (Ozaki). Kaikiri and

Nishimoto, 1995, p. 204.

Chlamys ashियाensis (Nagao). Nemoto and O'Hara, 2001, pl. 2, fig. 2. [not of Nagao, 1928b]

not *Chlamys* (*Minachlamys*) *namigataensis* (Ozaki). Masuda, 1962, p. 188, pl. 21, fig. 1. [*Chlamys* sp.]

Type specimens.—NSMT reg. no. P1-4379 (Holotype and paratypes). Although Ozaki (1956) noted a specimen registered under this number as the holotype, two unfigured specimens are also registered under the same number. They are paratypes.

Material.—MNHAH reg. nos. D1-018944 through D1-018951 (from MJ-2c), and D1-018952 (from MJ-4).

Emended diagnosis.—Moderate-sized *Chlamys* (*Leochlamys*) with 15 to 19 highly elevated radial ribs; fine radial threads appearing above ribs on ventral half of disc; left valve with an intercalary rib; radial sculptures densely imbricated; anterior auricle large, with a deep byssal notch and strong byssal fasciole on right valve; shell surface sculptured by a shagreen microsculpture.

Description.—Shell moderate in size, slightly higher than long, suborbicular, rather thin; apical angle between 85° and 95°; both valves with a shagreen microsculpture; lacking internal rib carinae.

Right valve weakly inflated; radial ribs 18 to 19, rather irregular, highly elevated, with three radial striations making ridges; ribs on both dorsal parts finer than those on center, finely imbricated; interspace of ribs rather deep, with or without an intercalary rib; anterior auricle large, sculptured by 6 to 7 fine radial ribs; byssal notch deep; ctenolium several in number, strong; byssal fasciole broad, strongly annulated; posterior auricle about half the length of the anterior one, with 7 to 8 radial ribs, weakly oblique anteriorly; resilifer pit moderate in size, with a weak resilifer tooth on both dorsal flanks; anterior dorsal tooth weak, long.

Left valve also weakly inflated; radial ribs 15 to 18, highly elevated, rather regular, with three sharp primary striations; an intercalary rib on each interspace; postero-dorsal part sculptured by fine, imbricated, radial striations; secondary radial striations appearing at about 40 mm from

← **Figure 6.** Mollusca from the Maéjima Formation (2). All specimens natural size, unless otherwise stated. All specimens whitened by magnesium oxide. **1, 6a–b.** *Cyclocardia* sp. 1. Left valve, MNHAH reg. no. D1-018956, $\times 2$. 6a–b. Right valve. MNHAH reg. no. D1-018955. 6a. External view lacking umbonal and antero-ventral parts. 6b. Internal view, especially showing transported cardinal teeth, both of $\times 1.5$. Both specimens silicon rubber casts. **2.** Lucinidae gen. and sp. indet. Left valve, MNHAH reg. no. D1-018954, silicon rubber cast, $\times 2$. **3, 10.** *Maetra?* sp. 3. Internal view of left valve, MNHAH reg. no. D1-018969, 10. Internal view of right valve, MNHAH reg. no. D1-018968. Both specimens silicon rubber casts, $\times 2$. **4a–b.** *Tapes?* sp. MNHAH reg. no. D1-018971, $\times 2$. 4a. Internal view. 4b. External view. Silicon rubber cast. **5, 7, 8, 11.** *Megangulus maximus* (Nagao). 5. Internal view of right valve, MNHAH reg. no. D1-018965, $\times 2$. 7. Internal view of left valve, MNHAH reg. no. D1-018964, $\times 1.5$. 8. Left valve lacking posterior part of shell, MNHAH reg. no. D1-018961, $\times 1.5$. 11. Internal view of right valve lacking ventral part, MNHAH reg. no. D1-018962, $\times 2$. All specimens silicon rubber casts. **9a–b.** *Crassostrea* sp. Left valve, MNHAH reg. no. D1-018953. 14a. External view. 14b. Internal view. **12, 15.** *Chlamys* (*Leochlamys*) *namigataensis* (Ozaki). 12. Left valve lacking posterior half of shell. MNHAH reg. no. D1-018946. 15. Left valve lacking ventral part and anterior auricle. MNHAH reg. no. D1-018947. **13, 14.** *Isognomon* (*Hippochaeta*) *hataii* Noda and Furuichi. 13. Right valve, slightly compressed. MNHAH reg. no. D1-018928. 14. Right valve. MNHAH reg. no. D1-018925. Both specimens silicon rubber casts.

beak; striations on radial ribs and internal ribs tending to become imbricated ventralward with growth; anterior auricle sculptured by 10 to 14 fine, imbricated radial ribs; posterior auricle as in right valve.

Discussion.—Masuda (1962) considered the present species to be a member of the subgenus *Mimachlamys* Iredale, 1929, as a result of examination of a single right valve collected from the middle Miocene Kawazu Formation in Shimane Prefecture. However, his specimen has lower radial ribs, a shallower byssal notch and a broader apical angle, and is not referred to the present species.

The specimens from the Maéjima Formation have a large anterior auricle, deep byssal notch with strong ctenolium, and distinct shagreen microsculpture. The shagreen microsculpture is one of the diagnostic features of the tribe Chlamidini (Waller, 1993). Thus, the present species is referred to the subgenus *Leochlamys* MacNeil, 1967. The diagnosis of the present species is emended as above, adding the right valve features.

Recently, Nemoto and O'Hara (2001) figured a right valve specimen identified as *Chlamys ashियाensis* (Nagao, 1928b) from the upper Eocene or lower Oligocene Iwaki Formation of the Shiramizu Group in the Joban Coalfield, northeast Honshu, Japan. Their figured specimen (Nemoto and O'Hara, 2001, pl. 2, fig. 2) is, however, unmistakably referred to the present species. *Pecten (Chlamys) ashियाensis* Nagao, 1928b is distinguished from *Chlamys (Leochlamys) namigataensis* (Ozaki) by having a more compressed shell with more numerous, lower, more irregular radial ribs lacking dense imbrications.

Distribution.—Namigata Formation in Okayama Prefecture, Paleogene; Iwaki Formation of the Shiramizu Group in Fukushima Prefecture, late Eocene or early Oligocene; Maéjima Formation in Okayama Prefecture, Eocene or Oligocene.

Subclass Heterodonta
Order Veneroida
Superfamily Carditoidea
Family Carditidae
Subfamily Venericardiinae
Genus *Cyclocardia* Conrad, 1867

Cyclocardia sp. indet.

Figure 6.1, 6.6a–b

Material—MNHAH reg. nos. D1-018955 (from MJ-4), D1-018956 and D1-018957 (from MJ-5).

Description.—Shell small, ovate, longer than high, inequilateral, oblique anteriorly, weakly inflated; radial ribs 19 to 23, rather low, round-topped, less curved; radial ribs on anterior two-thirds of shell subequal to their interspaces and broader than them on posterior part; pallial line dis-

tinct; anterior adductor muscle scar ovate, distinct; posterior adductor muscle scar oblong, weakly impressed; inner ventral margin crenated.

Discussion.—A single articulated specimen and two right valves have been obtained. It is interesting that one specimen has a transposed hinge (Figure 6.6b).

Cyclocardia sp. from the Maéjima Formation closely resembles *Cyclocardia takedai* (Honda, 1980) (new name for *Venericardia elliptica* Takeda, 1953), from the middle to upper Eocene Poronai Formation of Hokkaido. However, the former species has round-topped radial ribs while those of the latter species are flat-topped.

Cyclocardia tokunagai (Yokoyama, 1924) from the lower Oligocene Asagai Formation in Fukushima Prefecture is another allied species. However, this species is distinguished from *Cyclocardia* sp. from the Maéjima Formation by having a more triangular, more inequilateral shell with longer posterodorsal margin, less curved ventral margin and more numerous radial ribs. The present species differs from *Cyclocardia siogamensis* (Nomura, 1935b), recorded from the lower-middle Miocene of Japan and Korea, in having a less inflated shell with lower and broader radial ribs.

Superfamily Tellinoidea
Family Tellinidae
Subfamily Tellininae
Genus *Megangulus* Afshar, 1969

Megangulus maximus (Nagao, 1928) comb. nov.

Figure 6.5, 6.7, 6.8, 6.11

Tellina maxima Nagao, 1928b, p. 80, pl. 4, figs. 8–10.

Angulus (Tellinides) maximus (Nagao). Oyama *et al.*, 1960, p. 200–201, pl. 61, fig. 6; Kamada, 1980, p. 333, pl. Pg-18, fig. 7; p. 334, pl. Pg-19, figs. 15, 16; p. 335, pl. N-93, fig. 4; Fuse and Kotaka, 1986, pl. 18, figs. 20, 21.

? *Angulus (Tellinides) maxima* (Nagao). Matsumoto, 1964, p. 106, pl. 1, fig. 14.

Type specimens.—IGPS coll. cat. nos. 36412 (Holotype) and 36452 (Paratypes).

Material.—MNHAH reg. nos. D1-018960 (from MJ-4), D1-018961 through D1-018963 (from MJ-5), and D1-018964 through D1-018965 (from MJ-6).

Description.—Shell rather small, transversely elongate subelliptical, thin, slightly inequilateral, compressed; anterodorsal margin weakly curved; anterior dorsoventral margin rounded; posterodorsal margin nearly straight, narrowly depressed along ligament; posterior end oblique, narrow, subtruncated; beak low, pointed, weakly opisthocline, situated slightly posterior to middle of shell; posterior ridge weak; shell surface nearly smooth, sculptured by faint, very

fine, commarginal growth lines which are periodically strengthened; growth lines also rather strengthened on ventral part; hinge plate narrow; both valves with two small cardinal teeth and a weak, thin, long lateral tooth; posterior tooth of right valve and anterior tooth of left valve weakly bifid; nymph low; adductor muscle scars and pallial line indistinct.

Discussion.—Oyama *et al.* (1960) transferred the generic position of *Tellina maxima* Nagao, 1928b to *Angulus* (*Tellinides*) without discussion. Indeed, a thin, compressed shell with small cardinal teeth and weak posterior ridge of the present species could well be identical with those of the type species of *Tellinides*, *Tellina timorensis* Lamarck. However, the anterolateral tooth of the present species is much longer and less oblique than that of the latter. *Tellina nitidula* Dunker (= *Fabulina hokkaidoensis* Habe, 1961), the type species of *Nitidotellina* Scarlato, 1961, also resembles *T. maxima* in having a thin, compressed shell, but the anterior end of the anterolateral tooth on the right valve is angularly pointed ventralward (see Habe, 1977, pl. 41, fig. 5). The most appropriate genus for *T. maxima* is *Megangulus* Afshar, 1969. Although the members of this genus generally have a larger and thicker shell with surface sculptured by commarginal grooves, I assign *Tellina maxima* Nagao, 1928b to it on the basis of the cardinal properties (see Matsukuma *et al.*, 1988 for precise internal shell features of the Recent species).

Megangulus maximus (Nagao, 1928b) is closely similar to *Peronidia ochii* Kamada, 1962, originally described from the upper Eocene or lower Oligocene Iwaki and Asagai formations in Joban Coalfield, Fukushima Prefecture, northeast Japan. However, the former species presents a shorter shell with a more rounded posteroventral margin than the latter one.

Angulus okumurai Taguchi, 1992, from the lower Miocene Yoshino Formation in Okayama Prefecture, also resembles the present species. However, the former species is distinguished from it in having a larger, more equilateral shell with orthogyrous beak and more rounded posterior margin. The precise generic position of *A. okumurai* is also dubious because the cardinal properties have not been sufficiently examined.

Tellina (*Peronidea*) *lutea t-matsumotoi* Otuka, 1940, originally described from the Miocene "Wakkauenbetu Formation" of northern Hokkaido is distinguished from the present species in having a larger shell with a beak situated more anteriorly, and longer, more produced posterior dorsoventral margin.

Tellina vestalioides Yokoyama, 1920 is easily distinguished from the present species by having a more inflated shell with a stronger posterior ridge, weakly concave posteroventral margin behind a posterior ridge, more distinctly truncated posteroventral margin, and stronger cardi-

nal teeth.

Although Matsumoto (1964) reported *Angulus* (*Tellinides*) *maximus* (Nagao) from the lower Miocene Ôga Formation in Shizuoka Prefecture, his figured specimen has a more inflated shell with a beak situated slightly anterior to the middle of the shell, and is not referred to the present species. The specimen from the Ôga Formation of Matsumoto (1964) is probably conspecific with *Hiatula minoensis* (Yokoyama) sensu Shibata and Kato (1988).

Distribution.—Funazu Sandstone Member of the Iojima Formation of the Okinoshima Group in Nagasaki Prefecture, late Eocene; Kishima Formation in Saga Prefecture, latest late Eocene to earliest early Oligocene; Yamaga Formation of the Ashiya Group in Fukuoka Prefecture, latest early to early late Oligocene; Kiwado and Taoyama Formations of the Hioki Group in Yamaguchi Prefecture, late Oligocene; Maéjima Formation in Okayama Prefecture, Eocene or Oligocene.

Superfamily Mactroidea
Family Mactridae
Subfamily Mactrinae
Genus *Mactra* Linnaeus, 1767

Mactra? sp. indet.

Figure 6.3, 6.10

Material.—MNHAH reg. nos. D1-018967 (from MJ-4), and D1-018968 through D1-018970 (from MJ-6).

Description.—Shell rather small, roundly subtrigonal, slightly longer than high, moderately inflated; hinge plate narrow; cardinal and lateral teeth rather weak; anterior and posterior lateral teeth thin; resilifer small, shallowly depressed.

Discussion.—On the basis of cardinal properties, this species is unmistakably referred to the family Mactridae. Unfortunately, the presence or absence of a lamellar plate between resilifer and nymph, and the mode of pallial sinus were not examined in the present material due to poor preservation. Thus, the generic assignment is provisional.

"*Mactra* sp." was regarded as one of the characteristic elements of the *Mactra-Acila* assemblage from the "Miocene" around the eastern part of the Seto Inland Sea (Itoigawa, 1983).

Acknowledgments

I would like to express my appreciation to Y. Yamamoto (Okayama University) for his valuable suggestions on the fossil localities and stratigraphy of the Maéjima Formation. Acknowledgments are also due to T. Kase (National Science Museum, Tokyo), J. Nemoto (Tohoku University), T. Sasaki (University Museum, University of Tokyo) and

H. Kato (Natural History Museum and Institute, Chiba) for their kind assistance in examining specimens. I am indebted to H. Saegusa (Museum of Nature and Human Activities, Hyogo Himeji Institute of Technology) and Y. Suzuki (National Science Museum, Tokyo) for their cooperation in collecting references. I am grateful to G. J. Vermeij (University of California at Davis) and K. Amamo (Joetsu University of Education) for reviewing the manuscript and providing valuable comments. This study was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Sciences (no. 12740293).

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